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Effects of Appliance Standards on Product Price and Attributes: An Hedonic Pricing Model[1]

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Abstract
The tradeoffs between energy efficiency gains and product attributes as a result of the implementation of federal energy performance standards are examined. Hedonic pricing relationships are used to estimate changes in standardized marginal attribute prices for freezer volumes, food volumes, and annual energy consumption for refrigerators and refrigerator/freezers. From 1987/88 to 1993, energy performance standards significantly reduced energy consumption and at the same time, a historical decline in "quality-adjusted" real prices continued without disruption and consumers appeared to experience a welfare gain as a result of improving levels of energy efficiency.

1. Introduction

The Energy Policy and Conservation Act (P.L. 94-163), as amended by the National Appliance Energy Conservation Act of 1987 (P. L. 100-12) and by the National Appliance Energy Conservation Amendments of 1988 (P.L. 100-357), and by the Energy Policy Act of 1992 (P.L. 102-486), provides for the creation of energy conservation standards for 12 major classes of consumer appliances (NAECA, 1987; Federal Register 1995, 37388-415). Most energy standards set under this legislation are performance rather than prescriptive types of regulation and as a result, the technology to achieve compliance is determined by manufacturers. A number of reasons have been suggested for the implementation of stand-

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ards, including the avoidance of pollutants from the usage of energy, the more economically efficient allocation of non-renewable resources, and the avoidance of a segmented market as state authorities instituted their own standards. Addressing the primary reason for such standards, existing standards are expected to prevent the release of 107 million tons of carbon dioxide, 286 million tons of nitrous oxides and 385,000 tons of sulfur dioxide emissions in the year 2000, all of which are either greenhouse gases or ozone precursors (U.S. DOE 1993).

In the process of setting federal energy performance standards, the U.S. Department of Energy considers a variety of factors, including changes in product characteristics, technical feasibility, economic impacts on consumers and on manufacturers, life-cycle savings in operating costs, projected aggregate energy savings, and usefulness or utility[2] of the good. Minimum efficiency standards for refrigerators are defined for seven "product classes" and are specified as a function of "adjusted volume", which accounts for the difference in temperature and size of food and freezer compartments[3] (Federal Register, 1995, 37388-415; Turiel, et al, 1990). Product classes are defined by the type of defrost system, location of the freezer compartment, and inclusion of through-the-door ice or water service. The maximum allowable energy consumption is a function of adjusted unit volume, and increases with size in each product class. Adjustments are also provided for energy-intensive features such as through-the-door ice or water dispensers. The standards are progressively more stringent with time; the allowable levels of energy consumption under the 1993 standards are 25 to 30 percent lower than those under the 1990 standards (AHAM 1995a).

Previous studies of the effects of efficiency regulations have focused on the absolute changes in appliance purchase price and operating cost in real terms on an aggregate basis (U.S. DOE 1995). Arguably, however, the imposition of a performance standard may have also affected the non-energy efficiency-related characteristics of the regulated products, such as shelving and bin configurations. Indeed, a major issue in the policy debate over energy performance standards is what, if any, trade-offs may have been imposed among size, features, and price in the course of requiring energy efficiency gains. Finally, previous studies have also neglected to address the issues of possible surplus transfers resulting from the standard setting process.

The technique of hedonic regression is a standard method of analyzing the relationships between the prices of goods and the goods' characteristics. This is a particularly useful technique for evaluating the effects of technological change on the price of a good. Conventional price indices, e.g. the Consumer Price Index (CPI), assume that the characteristics of a good remain the same throughout time. However, where technological progress has occurred and performance-related attributes of a product have changed, exact price indices are no longer meaningful (Bitros and Panas 1988, 167-186; Triplett 1975, 1986,

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2 Utility in this application follows the conventional English usage, meaning usefulness to the consumer, i.e. this is not utility defined in a microeconomic theoretic sense.

3 The seven product classes are: (1) Manual defrost refrigerators and refrigerator/freezers; (2) Partial auto-defrost refrigerator/freezers; (3) Top-mount auto-defrost refrigerator/freezers; (4) Side-mount auto-defrost refrigerators/freezers; (5) Bottom-mount auto-defrost refrigerator/freezers; (6) Top-mount auto-defrost refrigerator/freezers with through the door features; (7) Side-mount auto-defrost refrigerator/freezers with through the door features. Adjusted volume in cubic feet is the sum of the food volume and 1.63 of the freezer volume, with the exception of manual defrost refrigerators and single door auto-defrost refrigerators where adjusted volume is the sum of the food volume and 1.44 of the freezer volume.

36-40, 1989). Hedonic methods have been applied to evaluate the effects on prices of changes in quality of several types of durable goods. Beginning with the pioneering study of Court (1939) on automobile prices, the technique has found widespread application in the estimation of price indices that control for changes in product quality or technical innovation. Another well known example is computers (Chow 1967, 1117-30). Previous applications of the hedonic method to refrigerators include Dhrymes (1971), Triplett and McDonald (1977, 137-156) and Gordon (1990). The latter work was directed, in part, at obtaining price indices controlled for changes in energy efficiency. It did not, however, attempt to measure the impact of regulation such as energy performance standards. Further, none of the previous hedonic studies of refrigerators have made an attempt at estimating the welfare effects resulting from quality changes. Although, it has been demonstrated that hedonic indices may provide exact measures of consumer surplus under some very restrictive conditions (Feenstra, 1993).

The work presented here is a retrospective analysis of the effect of U.S. energy performance standards on product attributes and prices to the consumer of refrigerators/freezer units using hedonic pricing techniques. We examine the effects of the 1990 and 1993 national efficiency standards on "quality-adjusted" prices consumers paid for refrigerators through the estimation of real prices for units comparable in size and energy consumption with the 1987 pre-standard model across years and across standard levels. Further we examine price structure through the comparison of marginal attribute prices for each energy efficiency level for each year to determine if standards affected that structure. Finally, we estimate a measure of surplus gained by consumers as a result of the implementation of energy performance standards; however, we cannot estimate either the gain/loss of producer surplus or total societal surplus with these techniques. Our results indicate that (1) product quality, defined in terms of food volume storage or other service providing attributes, was unaffected while energy efficiency increased; (2) real prices to consumers adjusted for secular effects did not increase; (3) "quality-adjusted" real prices declined during the period of analysis; (4) consumers experienced a welfare gain as a result of improving levels of energy efficiency. Interpretation of our results must consider the limited (6-year) time period available for analysis, the confounding factors of a business cycle along with changes in appliance market structure and inherent limitations of the data set. The remainder of the paper is organized as follows. Section 2 provides the theoretical basis for our empirical model and the data used to estimate the hedonic models. Section 3 presents the empirical results, while the final section provides brief concluding remarks.

2. Estimation of The Hedonic Price Relationship

This section summarizes the theoretical model, the estimation techniques and the data utilized in making the estimates of the hedonic price relationship between sales price and various attributes of refrigerators, such as volume, annual energy usage, and interior amenities, the estimation of marginal attribute prices, and welfare gains by consumers as a result of increases in energy efficiency.

2.1. Estimation of Hedonic Relationship

The *hedonic hypothesis* assumes that a household derives utility from a vector of attributes that a good possesses; further that each attribute has a shadow price with which can be used to approximate the true price index of a good without knowledge of the other technologies

in the household or household preferences. As a result, hedonic pricing relationships generated with the appropriate flexible form may be used to evaluate the welfare effects of changes in quality. To achieve the objectives of this study, we used a flexible functional form and the second of two variants of the hedonic method to estimate the impact of standards on the prices (Muellbauer 1974, 977-94): (1) estimation of single year cross-section regressions; (2) estimation of pooled (over at least two years) time-series/cross section regressions. The first form estimates the "shadow prices" of the "characteristics" of the goods for a given year; the second form utilizes time dummy variables, which link the cross-sections, and are intended to pick up the secular effects (effects of time) and separate them from quality-adjusted changes in price. In both methods the quality of the good is related to measurable specification variables, such as size, various attributes, energy usage, etc.

A number of flexible functional forms have been applied to the estimation of hedonic price relationships. A quadratic semi-log functional form was used in the estimation of the models presented here. Use of this type of flexible functional form allows for the underlying non-linearities in the hedonic price function and assumes weak seperability between various attributes; alternative specifications, such as a Box Cox transformation, are difficult to interpret for economic meaning and often result in less precise point estimates (Cropper, Deck and McConnell 1988, 668-75; Rasmussen and Zuehlke 1990, 431-38). Using the work of Rasmussen and Zuehlke (1990, 431-38), the functional form used in this analysis is as follows:

$$\ln(P) = \alpha + \varphi t + \delta' X + 0.5 X' \beta X + \gamma D + \varepsilon, \tag{1}$$

where

P = selling price of a refrigerator/freezer unit;
$\alpha, \delta, \beta, \gamma, \varphi$ = estimated parameters;
t = binary variable representing year of sale;
X = continuously specified product attributes; and
D = product attributes specified as binary variables.

Marginal attribute prices for individual product attributes may be defined as the partial derivative of price with respect to the attribute and are linear functions of the estimated coefficients and explanatory variables utilizing the following expression:

$$\frac{\partial P}{\partial X} = P(\delta + \beta X)'. \tag{2}$$

The coefficients of the quadratic terms are particularly useful for our analysis; they are the rates of change in the standardized marginal attribute prices with respect to each continuously specified attribute, i.e. marginal rates of substitution. As a result of this type of specification for the analysis of refrigerator sales data, trade-offs between food and freezer compartment volumes and increases in energy efficiency, i.e., decreases in annual energy usage, may be evaluated with respect to changes in selling price. The functional form expressed in equation (1) was estimated with a weighted generalized least squares on grouped data utilizing as a weight the square root of the number of units sold for each observation reported in the data set; due to the ill-conditioning of the data, parameter estimates were verified with a weighted orthogonal transformation (Gentleman-Givens). Group-wise heteroscedasticity was corrected by weighting each observation within the data set with the inverse of freezer volume.

To estimate the impacts of standards on price, two lines of evidence were examined.

Standardized marginal attribute prices were evaluated around the mean of food volumes, freezer volumes, and annual energy use for each year for three different standard levels, i.e. units not meeting standards and meeting the 1990 and 1993 standard levels. Normalized real prices ($1987) for refrigerator/freezer units with the same food volume, freezer volume, and energy consumption were also evaluated. Further, consumer surplus gains from declines in energy consumption during the six year period are estimated utilizing the standardized marginal attribute price for annual energy consumption at the three energy efficiency levels (Feenstra, 1993; Varian, 1992). Due to the limitations of the data set, this measure of surplus is undoubtedly only approximate and should be viewed as such (Hanley and Spash, 1993).

2.2. Data

For the work presented here, data for monthly retail sales from a commercial source were used and supplemented with data on size and efficiency characteristics. Data on monthly refrigerator unit sales and average sales price by unit, size, features, region, and store type were extracted for ten months during the years 1987/88 and for the twelve months of each of 1990 and 1993 from the ELCAP data base (Elrick and Lavidge, 1993). Types of retailers represented in this source include independent retailers, department stores, and "super" stores or major discount outlets. Although the data represent sales of over 200,000 units every year, which is between two and three percent of all new refrigerators sold in the United States on an annual basis, the data are a sample of convenience of retailers who voluntarily participate in the survey. However, data are included on all of the classes of refrigerators sold. What distinguishes this data set is the report of the actual sales price to the consumer rather than list price as well as its inclusion of information on the attributes of the units sold.

Variables extracted from the ELCAP data set include manufacturer, model, number of units sold, weighted monthly sales price within each region/store type combination, and the attributes of these units including the presence of optional ice-makers, built in ice-makers, vegetable bins, meat bins, the combination of meat and vegetable bins, the absence of both types of bins, crispers with humidity controls, temperature controlled meat bins, wire shelves, wire shelves with a glass inset, and all glass shelves. These data were reported by four regions of the United States, which correspond to the four Census divisions. Purchases were also reported by three types of retail outlets, including traditional retail outlets, department stores, and discount or mass merchandisers. Data by model on cubic footage of total volume, fresh food volume, and freezer volume, and the average daily consumption of electricity from the Association of Home Appliance Manufacturers (AHAM 1986, 1987, 1989, and 1992) were used to supplement the ELCAP data set.

3. Empirical Results

3.1. Hedonic Pricing Relationship

Table 1 presents the estimation results for a pooled specification across time of our hedonic pricing model as well as from 1987/88 to 1990 and 1990 to 1993. The base period for our pooled model is 1987/88. The use of a pooled, time-series/cross-section model specification allows for the isolation of changes in price due to general "price" or secular effects over time from the effects of changes in quality, attributes or technology. Our coefficients for the year of sale indicate that, for all refrigerators represented in the sample, current prices increased by between 1.4 and 1.5 percent per year over the time period including 1987/88 through 1993; similar rates of secular change are reflected in the time

Table 1. Parameter Estimates for Hedonic Pricing Model

Variable Name (Standard Error of Estimate in Parentheses)	1987-1993[1]	1987-1990[2]	1990-1993[3]
Intercept	5.870 (0.05)	6.098 (0.07)	5.788 (0.05)
Sale in 1990	-0.026 (0.004)	-0.026 (0.004)	——
Sale in 1993	-0.108 (0.01)	——	-0.082 (0.003)
Volume of freezer compartment in cubic feet	0.159 (0.01)	0.030 (0.01)	0.169 (0.01)
Volume of food compartment in cubic feet	-0.024 (0.01)	-0.070 (0.01)	-0.013** (0.01)
Annual energy usage in kilowatt hours	-0.0003 (0.0001)	0.0003 (0.0001)	-0.0004 (0.0001)
Freezer volume * Freezer volume	0.005 (0.001)	-0.017 (0.002)	0.006 (0.001)
Freezer volume * Food volume	-0.002** (0.001)	-0.005 (0.001)	0.001** (0.001)
Freezer volume * Annual energy usage	-0.0001 (0.000)	0.0002 (0.00002)	-0.0001 (0.00001)
Food volume * Food volume	0.007 (0.001)	0.013 (0.001)	0.006 (0.0009)
Food volume * Annual energy usage	-0.00002 (0.00001)	-0.00001* (0.00001)	-0.00001 (0.00001)
Annual energy usage * Annual energy usage	0.0000001 (0.000)	0.000001 (0.00)	0.000001 (0.00)
Sale from warehouse discount outlets	-0.052 (0.002)	-0.041 (0.003)	0.047 (0.002)
Sale from department store outlets	0.023 (0.003)	0.022 (0.005)	0.03 (0.004)
Presence of wire shelves only	-0.193 (0.01)	-0.088 (0.02)	-0.197 (0.01)
Presence of glass shelves only	-0.087 (0.01)	0.002** (0.02)	-0.076 (0.01)
Presence of factory installed ice maker	0.041 (0.004)	0.060 (0.004)	0.034 (0.004)
Occurrence in Class 1: Manual defrost refrigerators and refrigerator/freezers. .	-0.063 (0.01)	-0.204 (0.01)	-0.042 (0.008)
Occurrence in Class 2: Partial auto-defrost refrigerator/freezers.	-0.036 (0.01)	-0.041 (0.01)	-0.018 (0.008)
Occurrence in Class 4: Side-mount auto-defrost refrigerator/freezers.	0.153 (0.01)	0.169 (0.01)	0.155 (0.005)
Occurrence in Class 5: Bottom-mount auto-defrost refrigerator/freezers.	0.216 (0.01)	0.272 (0.01)	0.199 (0.007)
Occurrence in Class 6: Top-mount auto-defrost refrigerator/freezers with through the door features.	0.218 (0.01)	0.178 (0.01)	0.256 (0.008)
Occurrence in Class 7: Side-mount auto-defrost refrigerator/freezers with through the door features.	0.378 (0.01)	0.357 (0.01)	0.379 (0.006)
Sale in the western region of U.S.	-0.008 (0.003)	-0.025 (0.004)	0.005* (0.003)
Sale in the southern region of U.S.	-0.018 (0.003)	-0.016 (0.004)	0.014 (0.003)
Sale in the midwestern region of U.S.	-0.014 (0.003)	-0.013 (0.004)	0.016 (0.003)

[1]F-statistic = 7557.209 $_{(0.0001,\ 25,\ 21857)}$, Adj-R^2= 0.8963, MSE = 0.1155, DW=0.753, First Order Autocorrleation = 0.623. Test of First and Second Moment Specification Chi Squared Statistic = 1084.99

[2]F-statistic = 3667.249 $_{(0.0001,\ 24,\ 13948)}$, Adj-R^2= 0.8632, MSE = 0.1122, DW=0.815, First Order Autocorrelation = 0.592. Test of First and Second Moment Specification Chi Squared Statistic = 815.19

[3]F-statistic = 7951.045$_{(0.0001,\ 24,\ 7909)}$, Adj-R^2 = 0.9046, MSE = 0.1112, DW=0.690, First Order Autocorrelation = 0.655. Test of First and Second Moment Specification Chi Squared Statistic = 1307.05

Difference between pooled and individual years. 1987 to 1990 F-statistic[25, 7910] = 377.11
1990 to 1993 F-statistic[25, 1765] = 10.42

* Insignificant at 0.050 level. **Insignificant at 0.10 level.

coefficients for the two sub-period models. Interpreting our time coefficients in light of estimates of historical trends observed by Gordon (1990) and other researchers, our results for changes in current price due to secular effects are broadly consistent with previously observed trends; for the time period 1948 through 1983, Gordon estimated an average, annual secular increase in current refrigerator/freezer prices of 1.07 percent. Similarly, estimates from the U.S. Department of Labor, Bureau of Labor Statistics (BLS) indicate a net increase in current prices of 0.1 percent from 1983 through 1986; and for the period 1987 through 1993 an average (geometric) increase of 1.2 percent per year was recorded. However, results of tests for the statistical difference between the three models (footnote on table 1) indicate that there is a difference between the pooled model and the two time periods (Chow 1960, 253-75). This suggests that the underlying determinants of price and the relationships among those determinants may have changed during the six year period of time that the two levels of standards were implemented.

In addition to "pure price" effects, other factors which have the most effect on price include volume of the freezer compartment, and membership in the upper level product classes. For our estimates, top mount, auto-defrost refrigerator/freezer units with an amenities configuration of both wire and glass shelves and an optional icemaker sold in independent retail outlets in the northeast region of the United States were used as the base class. As would be expected, changes in price are a function of increasing levels of product class and freezer volume. During estimation, a "bundling" of size and service- providing amenities proved coincident with product class, i.e., membership in higher product classes also often means increases in both size and the levels of service-providing amenities, such as more food storage bins, and through-the-door features; these amenities were difficult to "unbundle". Inclusion in the model of these additional variables results in a near form of collinearity accompanied by pathologies such as instability of coefficient signs and implausible coefficient magnitudes. Therefore, the "quality-adjusted" prices and standardized marginal attribute prices for food volumes and freezer volumes would reflect the increase in the occurrence of these types of amenities; this is particularly true since the occurrence of these types of amenities in our sample increased at about the same time as the implementation of energy efficiency standards[4] (Greening, et al, 1996). Further, the unexpected sign and magnitude on the volume of the food compartment also may be reflective of such a condition; membership in progressively higher classes has a much greater explanatory power and may be also reflecting increases in volume. The model estimation results presented on table 1 also indicate that location and type of retail outlet did have an effect on price.

Of particular relevance to answering our question concerning the impact of energy efficiency standards on refrigerator/freezer unit price are the coefficients of the annual energy consumption term and the interaction terms, particularly those which include annual energy use. The coefficients for annual energy usage are significant, but small, reflecting little impact of annual energy usage on the price of the basic unit; and since energy consumption is a non-linear function of both food and freezer volumes, these coefficients may be also

4 Shipment weighted figures from AHAM (1995b) indicate that during the period 1987/88 through 1993, that shipments of side-mount and bottom-mount refrigerators increased by 3.2 percent, while partial auto-defrost units declined by 2.5 percent. Units in these classes were on average 4 to 11 percent larger with a higher proportion having glass shelves and factory installed ice makers during the period of analysis.

reflecting changes in unit size. As previously noted, the interaction coefficients can be interpreted as marginal rates of substitution. The sign and magnitude of these parameters indicate that changes in food or freezer volumes in response to changes in annual energy consumption would also be small. This type of trade-off is illustrative of potential effects on product attributes from the implementation of standards. Although a direct test of the presence of standards would have been desirable through the inclusion of a binary variable for different energy efficiency standard levels, specification tests indicated that this variable was reflecting the effects of time rather than purely of standards. Therefore the impacts of standards must be considered through more indirect lines of evidence.

3.2. Standardized Marginal Attribute Prices

To differentiate the impacts of standards from other effects on prices, standardized marginal attribute prices for food volumes, freezer volumes, and for annual energy usage were evaluated around the mean of each variable for each standard level for each year. Standardized marginal attribute prices are probably a better indication of the effects of a given attribute on price than the individual coefficients of the regression model, because they include both the effects of the attribute as well as the effects of substitutes for a given attribute. Since standardized marginal attribute prices are linear functions of our parameter estimates, variances and the resulting confidence intervals may be generated through the use of the estimated covariance matrix of our hedonic relationship (Draper and Smith, 1981). Point estimates of real marginal attribute prices may be used to estimate real prices for comparably sized refrigerator/freezer units with the same energy consumption over the period of time that standards were imposed as well as between standard levels.

Table 2 presents the standardized marginal attribute prices for freezer and food compartment volumes, and annual energy consumption; parameters from the pooled specification for the entire period were utilized in the evaluation of the standardized marginal attribute prices and were limited to the 10 percent level of significance. Comparison of 95 percent confidence intervals of the standardized marginal attribute prices for each year and standard level indicates that there is no statistical difference for this value for either food or freezer volumes over the period of time or by standard level. This indicates that there was no change in the price structure faced by the consumer over the period of analysis. As would be expected, the standardized marginal attribute price for annual energy consumption was different for each level of standard. However, the correlation with price is extremely small. If we had seen a significant magnitude with a negative sign for increasing levels of energy efficiency, i.e. declining annual energy consumption, we might be able to suggest that consumers were exhibiting a preference for energy efficiency, particularly since all three energy efficiency levels were sold throughout the period of analysis; conversely if we had had a significant magnitude with a positive sign, we would conclude that the effects of standards on prices was discernible.

Point estimates of normalized prices across time and across levels of energy efficiency standard are also presented on table 2. We estimate that a refrigerator/freezer unit that meets the 1993 efficiency performance standard would cost eleven dollars ($1987) less than the average model that did not meet any standard (table 2); further that this same model would have cost between four and forty-six dollars ($1987) less at the 1990 efficiency performance standard level. The results presented for the 1993 standard levels in 1987 and 1990, as well as for pre-standard models sold in 1993, are not considered in this comparison due to the small representation of those classes in our sample, and the anomalous food volumes and

Table 2. Continuous Attributes, Standardized Marginal Attribute Prices, Normalized Prices			
(Standard deviation in parentheses)	Not Meeting Standards	Meets 1990 Standard	Meets 1993 Standard
1987			
Freezer Volume (cubic feet)	5.7 (1.5)	6.4 (1.8)	3.8 (3.3)
Food Volume (cubic feet)	13.6 (1.8)	13.9 (1.4)	12.3 (3.2)
Annual Energy Usage (kwh)	1149 (241)	981 (191)	548 (129)
Real Price ($1987)	772 (312)	729 (274)	737 (492)
Units represented in sample	114,609	42,801	19
Standardized marginal freezer volume price[1]	0.103 (0.03)	0.118 (0.03)	0.143 (0.02)
Standardized marginal food volume price[1]	0.144 (0.02)	0.152 (0.04)	0.138 (0.03)
Standardized mar. annual energy usage price[1]	0.001 (0.0002)	0.0008 (0.0002)	0.0001 (0.0001)
Normalized real price[2] ($1987)	772	726	971
1990			
Freezer Volume (cubic feet)	6.4 (1.8)	6.3 (1.9)	2.4 (0.2)
Food Volume (cubic feet)	13.3 (1.9)	14.1 (1.5)	6.6 (0.5)
Annual Energy Usage (kwh)	1235 (240)	1041 (220)	221 (42)
Real Price ($1987)	780 (322)	818 (328)	364 (29)
Units represented in sample	146,608	233,437	798
Standardized marginal freezer volume price[1]	0.102 (0.03)	0.119 (0.03)	0.161 (0.02)
Standardized marginal food volume price[1]	0.139 (0.03)	0.154 (0.04)	0.065 (0.02)
Standardized mar. annual energy usage price[1]	0.001 (0.0002)	0.0008 (0.0002)	-0.0002 (0.00006)
Normalized real price[2] ($1987)	681	768	639
1993			
Freezer Volume (cubic feet)	6.7 (1.5)	6.0 (1.8)	5.0 (1.8)
Food Volume (cubic feet)	14.8 (1.6)	14.1 (1.5)	13.2 (1.8)
Annual Energy Usage (kwh)	1156 (224)	939 (185)	669 (104)
Real Price ($1987)	820 (306)	738 (308)	612 (279)
Units represented in sample	1,785	67,190	82,367
Standardized marginal freezer volume price[1]	0.112 (0.03)	0.126 (0.03)	0.142 (0.02)
Standardized marginal food volume price[1]	0.161 (0.04)	0.156 (0.03)	0.149 (0.03)
Standardized marginal annual energy usage price[1]	0.001 (0.0002)	0.0006 (0.0002)	0.0002 (0.0001)
Normalized real price[2]	587	750	761

[1]Standardized marginal prices for each attribute may be converted to point estimates of real marginal attribute price by multiplication by the real price.

[2]Evaluated at the means of freezer volume, food volume, and annual energy consumption for units not meeting energy efficiency standard levels in 1987.

freezer volumes represented. The reversal of prices in 1990 and 1993 between standard levels may be indicative of other factors such as changes in the mix of product class, manufacturers, or discounting by retailers of discontinued models. Examining the differences between 1987 and 1993, real normalized prices essentially remained constant across time and probably declined.

3.3. Estimation of Consumer Surplus

Estimates of a consumer surplus measure were made with the standardized marginal attribute price for annual energy consumption. These estimates need to be considered as inexact measures, rather than an exact measure of a money metric for indirect utility, which may in certain very restricted instances be extracted from an estimated hedonic relationship (Feenstra, 1993). Since it has been demonstrated in the previous section that the standardized marginal attribute prices for both freezer and food volumes did not change significantly during the analysis period, nor did consumers appear to have strong preferences for energy efficiency as demonstrated by the standardized marginal attribute price for annual energy consumption, the assumption that this price reflects a true "willingness to pay" measure has to be considered with a great deal of caution. Both the signs and magnitudes of the standardized marginal attribute price for annual energy consumption could alternatively be interpreted as a manifestation of the mechanics of refrigerators/freezers.

Using the assumption that prices remained constant for both food and freezer volumes for the period of the analysis, and using the differences in the standardized marginal attribute price for annual energy consumption and quantities of electricity consumed for the same average size unit present in 1987 that did not meet any energy performance standard (see table 2), we estimate that consumers gained roughly $12 per average unit from increased energy efficiencies resulting from the implementation of the 1990 energy performance standards; for the 1993 energy performance standards, we estimate a gain of $116. To place this result in perspective, an alternative measure of gains that consumers make from the energy performance standards, might be the decrease in annual operating costs that consumers gain from each standard level. For the same average unit, assuming a price of 8 cents per kilowatt hour, consumers save approximately $13 per year under the 1990 standard levels and $30 per year under the 1993 standard levels. The total savings in energy expenditures that a consumer will accrue over the life-time of a refrigerator/freezer unit will of course vary with the local price of electricity, the assumed life of the unit, and discount rate that a consumer faces. Since the real, initial purchase price or first cost of a unit did not appear to increase, and since we have at least an indication of surplus gains by the consumer, we might venture the conclusion that for individual consumers, there was a welfare gain from the implementation of energy performance standards. However, this conclusion is tentative, and one for further research. Estimates of total societal welfare are even more difficult to obtain, since they must include marginal benefits of the avoided energy consumption (both locally and globally), the potential surplus loss by producers, and the transactions costs of the standard implementation process. All of these components, once again, are issues for further research.

3.4. Caveats or "What we cannot answer"

These results naturally raise the question of what price trends might have occurred in the *absence* of standards. Without benefit of controlled experimentation, our answer will of course be uncertain. We can only respond to this through examination of the historical record

and the research of others. Using hedonic techniques for the period 1949 through 1983, two different studies indicate that quality adjusted prices declined annually by between 0.68 and 1.11 percent (Gordon, 1990). Further insight along this line can be obtained from examining recent trends in the Consumer Price Index (CPI) for refrigerators and freezers from the U.S. Department of Labor, Bureau of Labor Statistics (BLS). The CPI is a Laspeyres or "fixed" market basket type of index with (currently) 1986 as a base year. During the same period as our analysis, current prices for refrigerators/freezers were increasing at approximately 1.2 percent per year according to the CPI, compared with our finding of between 1.4 and 1.5 percent per year during the period 1987/88 through 1993. As we have argued, much of the latter trend can be accounted for by secular or general price effects, so that the real price of the product was essentially unchanged.

As indicated by examination of actual sales data with a more fully specified set of attributes than that measured by the BLS, there has been a substantial shift towards a higher level of such amenities as more storage bins, factory-installed ice makers and through-the-door features. Thus, it is doubtful that in the case of this product the CPI is measuring a change in price for approximately the same product (Gordon, 1990; Triplett and McDonald, 1977). We are thus left with a question of assignment of causality in the presence of potential fallacy (*post hoc ergo proper hoc*) that cannot be approached without a longer time series of data which includes a number of additional variables such as detailed information about the households purchasing the units. Such additional data would allow for identification in a household production framework of possible changes in households' preferences for food preservation services. From our analysis, we can only say that our results are consistent with previously observed declines in "quality-adjusted" real prices that have resulted from a number of sources including improved manufacturing technology or new materials.

If real "quality-adjusted" prices to consumers declined, then questions of surplus transfer must be considered, i.e. were manufacturers negatively impacted by the standard through an increase in costs, which translates into a loss of profits. Without detailed information on the cost structure for manufacturers by product class, we can only surmise. Modernization of industry production methods for refrigerators/freezers did require capital investments over the period 1987 through 1992 of about twice the amount invested during the previous six years; this resulted in more automated operations, improved product lines, both factors in maintaining a presence in domestic and world markets, as well as compliance with energy regulation (AHAM, 1995a). Further, since the majority of manufacturers of refrigerator/freezer units also manufacturer other products, we do not know the levels of cross-subsidization that may have occurred from other product lines for these capital improvements. These capital investment costs may have been offset by the number of hours required to directly produce a refrigerator/freezer unit, which declined by 7 percent during the same period of our analysis; and industry figures indicate average annual labor productivity increases for the production of refrigerators/freezers of between 3 and 4.5 percent per year during this period. Also unknown are the cost savings that might have occurred from the introduction of innovative materials in the manufacturing process. Finally, during the period of 1989 through 1993 annual revenues as measured in current dollars from refrigerators/freezers were increasing at an average rate of about 4 percent per year (AHAM, 1995a); this increase was the result of increased demand for refrigerators/freezers and a shift in product shipment mix towards the higher product classes, which on a per unit basis are known to have higher profit margins. Analysis of net effects on manufacturers requires a detailed description of the cost function for a given product, for which these types of information

are not publicly available. Further unevaluated are surplus transfers that might have resulted within other segments of the market, i.e. between manufacturers and retailers. As a result, more research is needed to determine the impact of standards on manufacturer profits, as well as these other market segments.

4. Policy Implications and Conclusions

The analysis presented here has a number of implications for the future development of energy-efficiency regulation or standards for appliances. On the consumer side, the basic policy question regarding appliance efficiency standards is the standard's effect on food preservation services that consumers receive from refrigerator/freezer units that meet those standards. Our key finding is that the 1990 and 1993 standards did not result in an increase in "quality-adjusted" prices to the consumer and that price declines we observed in our analysis are consistent with historical trends. We cannot, however, rule out the possibility that standards decelerated or will decelerate that rate of decline; alternatively standards may in the long-run accelerate these trends. Shipment weighted rates of decline of per unit annual energy consumption, which were 4 to 5 percent per year just prior to our period of analysis, were definitely accelerated by the imposition of new standard levels; during the period 1987 through 1993 annual energy consumption declined at a rate of 8.5 percent per year. These findings are pertinent to several concerns that have been raised regarding the impact of the policy, namely that consumers might be faced with significant increases in first costs and that energy efficiency improvements might be gained at the expense of other attributes. These effects are not evident from our analysis of this data set. Conversely, however, although consumers appear to have gained from the implementation of standards through energy savings without cost increases as well as an improved product in other regards, we cannot rule out adverse impacts on manufacturers or other segments of the market.

To fully evaluate the effects of energy performance standards, including the calculation of standard measures of social surplus associated with changes in the provision of food preservation services, requires complete identification and quantification of the direct and indirect costs and benefits from such a policy. The primary hurdle in such research is the availability of data. In this regard, it is worth re-emphasizing the significance of the *ex post*, retrospective focus of this study. Reliance solely on prospective, forecasting approaches cannot ultimately lead to an understanding of their merits or shortcomings in practice.

References

Association of Home Appliance Manufacturers (AHAM). 1986. *1987 Directory of Certified Refrigerators/Freezers*. Chicago, Ill.: Association of Home Appliance Manufacturers.

Association of Home Appliance Manufacturers (AHAM). 1987. *1988 Directory of Certified Refrigerators/Freezers*. Chicago, Ill.: Association of Home Appliance Manufacturers.

Association of Home Appliance Manufacturers (AHAM). 1989. *1990 Directory of Certified Refrigerators/Freezers*. Chicago, Ill.: Association of Home Appliance Manufacturers.

Association of Home Appliance Manufacturers (AHAM). 1992. *1993 Directory of Certified Refrigerators/Freezers*. Chicago, Ill.: Association of Home Appliance Manufacturers.

Association of Home Appliance Manufacturers (AHAM). 1995a. *AHAM Fact Book: A Comprehensive Reference on the United States Major Home Appliance Industry*. Chicago, Ill.

Association of Home Appliance Manufacturers (AHAM). 1995b. Industry Statistics. Chicago, Illinois.

Bitros, George C., and Epaminondas E. Panas. 1988. "Measuring Product Prices Under Conditions of

Quality Change: The Case of Passenger Cars in Greece." *Journal of Industrial Economics* 37(2): 167-186.

Chow, Gregory C. 1960. "Tests of Equality Between Sets of Coefficients in Two Linear Regressions." *Econometrica* 28: 253-75.

Chow, Gregory C. 1967. "Technological Change and the Demand for Computers." *American Economic Review,* 57 (December): 1117-1130.

Court, A.T. 1939. "Hedonic Price Indexes with Automotive Examples." In *The Dynamics of Automobile Demand.* Detroit: General Motors Corporation.

Cropper, Maureen L., Leland B. Deck, and Kenneth E. McConnell. 1988. "On the Choice of Functional Form for Hedonic Price Functions." *The Review of Economics and Statistics* 70 (4): 668-675.

Dhrymes, Phoebus J. 1971. "Price and Quality Changes in Consumer Capital Goods: An Empirical Study." In *Price Indexes and Quality Change*, edited by Zvi Griliches. Cambridge, Mass.: Harvard University.

Draper, N.R., and H. Smith. 1981. *Applied Regression Analysis*, Second Edition. New York: John Wiley & Sons.

Elrick and Lavidge. 1993. ELCAP Consumer Appliance Purchases Database. Atlanta, Georgia.

Federal Register. 1995. Proposed Rulemaking Regarding Energy Conservation Standards for Refrigerators, Refrigerator-Freezers, and Freezers. 60(139): 37388-37415.

Feenstra, Robert C. 1993. "Measuring the Welfare Effect of Quality Change: Theory and Application to Japanese Autos." National Bureau of Economic Research, Working Paper No. 4401.

Gordon, Robert. 1990. *The Measurement of Durable Goods Prices.* Chicago: University of Chicago Press.

Greene, William H. 1993. *Econometric Analysis*, Second Edition. New York: Macmillan Publishing Company.

Greening, Lorna A., Alan Sanstad, James E. McMahon, Tom Wenzel, and Steven J. Pickle. 1996. "Retrospective Analysis of National Energy-Efficiency Standards for Refrigerators." Forthcoming in American Council for an Energy-Efficient Economy *Proceedings from the 1996 Summer Study on Energy Efficiency in Buildings.*

Hanley, Nick, and Clive L. Spash. 1993. *Cost-Benefit Analysis and the Environment.* Brookfield, Vermont: Edward Elgar Publishing Company.

Muellbauer, John. 1974. "Household Production Theory, Quality, and the "Hedonic Technique"." *The American Economic Review* 14(6): 977-994.

National Appliance Energy Conservation Act (NAECA). 1987. Public Law 100-12, March 17, 1987.

Rasmussen, David W., and Thomas W. Zuehlke. 1990. "On the Function Form for Hedonic Price Functions." *Applied Economics* 22: 431-438.

Triplett, Jack E. 1975. "Consumer Demand and Characteristics of Consumption Goods." In *Household Production and Consumption,* edited by Nestor E. Terleckyj. New York: National Bureau of Economic Research.

Triplett, Jack E. 1986. "The Economic Interpretation of Hedonic Methods." *Survey of Current Business* 66(1): 36-40.

Triplett, Jack E. "Price and Technological Change in a Capital Good: A Survey of Research on Computers." In *Technology and Capital Formation,* edited by Dale W. Jorgenson and Ralph Landau. Cambridge, Mass.: The MIT Press.

Triplett, Jack E., and Richard J. McDonald. 1977. "Assessing the Quality Error in Output Measures: The Case of Refrigerators." *The Review of Income and Wealth* 23(2): 137-156.

Turiel, Isaac, Douglas Berman, Peter Chan, Terry Chan, Jon Koomey, Benoit Lebot, Mark D. Levine, James E. McMahon, Greg Rosenquist, and Steve Stoft. 1990. "U.S. Residential Appliance Energy Efficiency: Present Status and Future Directions." In *Proceedings from the American Council for an Energy-Efficiency in Buildings*, Vol. 1, Building Equipment and Appliances.

U.S. Department of Commerce. 1994. *U.S. Industrial Outlook.* Washington, D.C.

U.S. Department of Energy (DOE). 1993. *Technical Support Document: Energy Efficiency Standards for Consumer Products—Room Air Conditioners, Water Heaters, Direct Heating Equipment,*

Mobile Home Furnaces, Kitchen Ranges and Ovens, Pool Heaters, Fluorescent Lamp Ballasts and Television Sets. Office of Codes and Standards, DOE/EE-0009.

U.S. Department of Energy (DOE). 1995. *Technical Support Document: Energy Efficiency Standards for Consumer Products- Refrigerators, Refrigerator/Freezers, and Freezers.* Office of Codes and Standards, DOE/EE-0064.

Varian, Hal R. 1992. *Microeconomic Theory*, Third Edition. New York: W. W. Norton & Company.